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12-M-1565

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NATIONAL BUREAU OF STANDARDS

THIRTY FOURTH MONTHLY REPORT OF PROGRESS ON THE COMBUSTION CHAMBER RESEARCH PROGRAM

References: (a) Order NAcr 00543;
(b) NBS Project 3758.

Exhaust Reheat for Thrust Augmentation. On 19 October drawings of an exhaust reheater were sent to AEL, Philadelphia, for use in connection with Project TED-NAM 04597. A copy of these drawings was included in the preceeding report.

Fuel Test Program. A G.E. I-16 combustion chamber has been installed and the testing of fuels in this burner will begin early in November. A photograph of the installation is included as Figure 1.

Ram Jet Experiments. (a) 7" Burner. Combustion experiments have been continued using liquid fuel injection in the 7" burner. Ignition and stable combustion have been possible at the maximum air velocity attainable, but combustion efficiency is still low.

The present 7" burner consists of a 48" length of 7" i.d. tubing downstream from a 7 1/2° diffuser, this diffuser being 5 1/2" i.d. at its small end. In all tests annular, cone-type flame holders were located 6" downstream from the diffuser outlet. One flame holder consisted of a single ring, 3 1/2" in mean diameter, shaped in the form of an annular 30° cone, 3/4" across at the downstream end. The other consisted of two similar rings, 1 3/4" and 5 1/4" in mean diameter. The fuel was injected at the diffuser inlet in some cases, and at the outlet in others. Injection in the first case was through open-end stub tubes, 3, 6 and 9 being tried. The distance which these stub tubes projected into the air stream was also varied. Injection at the diffuser outlet was through perforated coplanar rings. Both injectors operated at fuel pressures from 5 to 15 lb per sq in.

As already stated, ignition and stable combustion were possible up to the maximum air velocity attainable (about 160' per sec), but the combustion efficiency was of the order of 70%. Best results were obtained when the fuel was injected at the diffuser inlet, where the gasoline is atomized by the high-velocity air stream flowing across the stub tubes.

These experiments will be continued using longer burners, and with the hollow flame holders filled with asbestos wicking, upon which liquid fuel will be dropped during the burning.

Ram Jet Experiments. (b) Survey of the Effect of Burner Length in a 4" Ram Jet. Initial combustion experiments in the 4" burner with movable flame holder (see Figure 3, 31st report) have indicated that the flow distribution upstream has considerable effect upon the length of the tail pipe which can be used while maintaining smooth combustion. With poor upstream distribution it was very difficult to initiate smooth burning if the tail pipe extended more than 2' beyond the flame holder. However with smooth upstream flow, smooth combustion was obtained at all tail pipe lengths up to 40". In general, short burners are easier to start under all inlet conditions.

Longitudinal surveys of static pressure have been made during burning with symmetrical inlet flow, inlet mixture velocity being varied between 110 and 190' per sec and tail pipe length being increased from 24 to 40". No irregularties in pressure have been observed under any operating condition. Combustion was initiated and the inlet velocity was brought to any chosen value with the flame holder 24" from the end of the burner, and the longitudinal pressure distribution was observed. The flame holder was then moved upstream in 4" steps, pressure readings being taken at each position for known values of mixture ratio and inlet velocity. This procedure was then repeated at another inlet velocity. The results of these measurements are presented in Table I. Figure 2 shows typical pressure distribution curves, in this instance corresponding to the run of highest inlet velocity. Curves for other velocities are similar, except for the pressure level in the burner.

From the pressure data it is possible to calculate approximate values of average temperature and velocity at the pressure stations. Figure 3 shows the average temperature distribution along the burner, estimated in this manner from the data of Table I. The average deviation of individual results from the curve is ±3% and the maximum is 12%.

From these results it appears that the rise in temperature along the burner tube is practically independent of inlet velocity, but some change in the length of burner which becomes visibly red can be noted with changing velocity.

The downstream end of this burner has become deformed with use and will have to be replaced before the burner can be used again.

NACA Sub-Committee on Combustion. The first meeting of this Sub-Committee, held in Cleveland on 26 October, was attended by Lt. Comdr. Redding of Bu Aer and Fiock of NBS. Future needs for combustion research were discussed in a general way, and a Panel with Fiock as Chairman was appointed to bring in recommendations on nomenclature and definitions applicable in the field of combus-

tion. The assembly of preliminary material for consideration by the Panel has been undertaken.

Collaboration in Preparation of Summary Report on Ram Jets. At the request of representatives of Bu Aer, Flock has collaborated in the preparation of a summary report on the present status of ram jets by writing the section on combustion chambers.

NATIONAL BUREAU OF STANDARDS

Washington, D. C.
November 5, 1945
EFF:BHD

Table I.

Results of Longitudinal Pressure Surveys in the 4" Ram Research Burner

Series 1. Inlet Conditions: $W_a = 0.75$; $W_f = 0.038$; $W_a/W_f = 19.7$; $V_1 = 108$; $M_1 = 0.096$; $p_{s1} = 1.1$; $p_{t1} = 1.1$; $q_{c1} = 0.0071$; $T_1 - 460 = 65$.

Station* No.	Observed Static Pressures for Tail Pipe Lengths as Shown					
	24"	28"	32"	36"	40"	44"
	Atm Abs					
0	1.000	1.000	1.000	1.000	1.000	1.000
4	1.016	1.008	1.005	1.003	1.002	1.002
8	1.037	1.024	1.013	1.007	1.003	1.003
12	1.057	1.043	1.028	1.017	1.008	1.006
16	1.070	1.063	1.048	1.033	1.020	1.012
20	1.075	1.074	1.064	1.050	1.033	1.022
24	1.082	1.082	1.077	1.066	1.050	1.033
28	-----	1.089	1.084	1.079	1.067	1.053
32	-----	-----	1.092	1.085	1.079	1.069
36	-----	-----	-----	1.092	1.087	1.080
44	-----	-----	-----	-----	-----	1.094

Maximum tail pipe length for smooth combustion - 46 1/2".

Calculated Conditions for Tail Pipe Lengths as Shown

	24"				32"				44"			
	V_2	T_2-460	$T_{2t}-460$	T_{2t}/T_{1t}	V_2	T_2-460	$T_{2t}-460$	T_{2t}/T_{1t}	V_2	T_2-460	$T_{2t}-460$	$T_{2t}-T_{1t}$
	ft/sec	°F			ft/sec	°F			ft/sec	°F		
0	760	2950	2990	6.57	840	3250	3290	7.15	855	3320	3360	7.28
4	640	2450	2480	5.60	800	3100	3140	6.86	840	3280	3320	7.20
8	480	1770	1790	4.28	740	2860	2890	6.38	830	3230	3270	7.10
12	330	1100	1110	2.99	625	2390	2410	5.47	810	3150	3190	6.95
16	230	650	650	2.11	475	1740	1760	4.23	755	2930	2960	6.51
20	190	460	460	1.75	350	1200	1210	3.18	690	2670	2700	6.02
24	108	65	65	1.00	255	750	750	2.30	605	2310	2330	5.32
28	---	--	--	----	200	500	500	1.83	455	1660	1670	4.06
32	---	--	--	----	108	65	65	1.00	325	1070	1080	2.93
36	---	--	--	----	---	--	--	----	245	710	710	2.23
44	---	--	--	----	---	--	--	----	108	65	65	1.00

*By station number is meant the distance in inches from the end of the burner to the pressure tap.

Table I, Page 2.
Results of Longitudinal Pressure Surveys in the 4" Ram Research Burner

Series 2. Inlet Conditions: $W_a = 1.05$; $W_f = 0.055$; $W_a/W_f = 19.1$; $V_1 = 145$; $M_1 = 0.13$; $p_{s1} = 1.2$; $p_{t1} = 1.2$; $q_{c1} = 0.013$; $T_1 - 460 = 85$.

Station* No.	Observed Static Pressures for Tail Pipe Lengths as Shown				
	24"	28"	32"	36"	40"
	Atm Abs				
0	1.000	1.000	1.000	1.000	1.000
4	1.047	1.027	1.013	1.008	1.005
8	1.074	1.060	1.032	1.020	1.012
12	1.113	1.098	1.063	1.040	1.023
16	1.140	1.128	1.107	1.075	1.048
20	1.153	1.147	1.150	1.107	1.077
24	1.163	1.153	1.160	1.150	1.110
28	-----	1.173	1.173	1.160	1.143
32	-----	-----	1.187	1.173	1.163
36	-----	-----	-----	1.187	1.173

Maximum tail pipe length for smooth combustion - 42".

Calculated Conditions for Tail Pipe Lengths as Shown

	24"				32"				40"			
	V_2 ft/sec	T_2-460 °F	$T_{2t}-460$ °F	T_{2t}/T_{1t}	V_2 ft/sec	T_2-460 °F	$T_{2t}-460$ °F	T_{2t}/T_{1t}	V_2 ft/sec	T_2-460 °F	$T_{2t}-460$ °F	T_{2t}/T_{1t}
0	1070	3000	3070	6.47	1230	3410	3500	7.26	1230	3410	3500	7.26
4	870	2450	2500	5.43	1200	3260	3350	6.99	1205	3340	3430	7.13
8	660	1810	1840	4.22	1060	2970	3040	6.42	1175	3280	3360	7.00
12	455	1170	1190	3.03	885	2490	2540	5.50	1115	3130	3200	6.72
16	290	610	620	1.98	625	1710	1740	4.03	970	2740	2800	5.98
20	235	410	410	1.60	400	990	1000	2.68	810	2290	2330	5.06
24	145	85	85	1.00	345	800	810	2.31	625	1720	1740	4.03
28	---	--	--	----	290	610	620	1.96	465	1200	1220	3.08
32	---	--	--	----	145	85	85	1.00	350	810	820	2.35
36	---	--	--	----	---	--	--	----	290	610	620	1.98
44	---	--	--	----	---	--	--	----	145	85	85	+---

*By station number is meant the distance in inches from the end of the burner to the pressure tap.

Table I, Page 3.

Results of Longitudinal Pressure Surveys in the 4" Ram Research Burner

Series 3. Inlet Conditions:	----W_a = 1.41; W_f = .080; W_a/W_f = 17.6 ----			----W_a = 1.44; W_f = .080; W_a/W_f = 18.0----			
V_1	180	170					165
M_1	.16	.15					.15
p_{s1}	1.3	1.4					1.4
p_{t1}	1.3	1.4					1.4
q_{c1}	.022	.021					.021
T_1-460 ...	95	95					70

Observed Static Pressures for Tail Pipe Lengths as Shown

Station No.	24"	28"	32"	36"	40"	40"	44"	48"
	Atm Abs							
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
4	1.077	1.060	1.033	1.023	1.017	1.010	1.010	1.013
8	1.140	1.117	1.070	1.040	1.027	1.023	1.022	1.020
12	1.203	1.183	1.137	1.083	1.050	1.050	1.037	1.030
16	1.253	1.250	1.213	1.147	1.097	1.097	1.067	1.047
20	1.273	1.290	1.270	1.207	1.150	1.150	1.103	1.067
24	1.300	1.313	1.310	1.267	1.213	1.217	1.157	-----
28	-----	1.347	1.333	1.310	1.277	1.280	1.220	-----
32	-----	-----	1.357	1.333	1.320	1.320	1.277	-----
36	-----	-----	-----	1.353	1.340	1.343	1.317	-----
44	-----	-----	-----	-----	-----	-----	1.357	-----

Calculated Conditions for Tail Pipe Lengths as Shown

	24"				32"				44"			
	V_2 ft/sec	T_2-460 °F	T_{2t}-460 °F	T_{2t}/T_{1t}	V_2 ft/sec	T_2-460 °F	T_{2t}-460 °F	T_{2t}/T_{1t}	V_2 ft/sec	T_2-460 °F	T_{2t}-460 °F	T_{2t}/T_{1t}
0	1450	2950	3080	6.38	1630	3460	3620	7.35	1600	3300	3450	7.37
4	1130	2390	2470	5.28	1510	3290	3430	7.01	1570	3260	3410	7.30
8	875	1890	1940	4.32	1340	2990	3100	6.42	1520	3190	3330	7.15
12	630	1320	1350	3.26	1060	2440	2510	5.35	1470	3120	3250	7.00
16	425	790	800	2.27	780	1800	1840	4.15	1340	2890	3000	6.52
20	345	570	580	1.87	535	1170	1190	2.97	1200	2660	2750	6.05
24	180	95	95	1.00	375	710	720	2.13	990	2230	2290	5.18
28	---	--	--	----	290	460	470	1.68	740	1670	1710	4.09
32	---	--	--	----	170	95	95	1.00	510	1080	1100	2.94
36	---	--	--	----	---	--	--	----	360	660	670	2.13
44	---	--	--	----	---	--	--	----	165	70	70	1.00

Table I, Page 4.

Results of Longitudinal Pressure Surveys in the 4" Ram Research Burner

Series 4. Inlet Conditions: ----W_a = 1.71; W_f = .104; W_a/W_f = 16.5 ----

V_1	190	180
M_1	.17	.16
p_{s1}	1.5	1.6
p_{t1}	1.5	1.6
q_{c1}	.029	.028
T_1-460	80	80

Observed Static Pressures for Tail Pipe Lengths as Shown

Station No.	24"	32"	40"	44"
	Atm Abs			
0	1.000	1.000	1.000	1.000
4	1.113	1.050	1.023	1.023
8	1.237	1.120	1.040	1.043
12	1.347	1.200	1.077	1.060
16	1.420	1.313	1.147	1.107
20	1.457	1.407	1.227	1.157
24	1.473	1.473	1.323	1.233
28	-----	1.510	1.417	1.333
32	-----	1.533	1.483	1.423
36	-----	-----	1.523	1.490
44	-----	-----	-----	1.533

Calculated Conditions for Tail Pipe Lengths as Shown

	24"				32"				44"			
	V_2 ft/sec	T_2-460 °F	T_{2t}-460 °F	T_{2t}/T_{1t}	V_2 ft/sec	T_2-460 °F	T_{2t}-460 °F	T_{21}/T_{1t}	V_2 ft/sec	T_2-460 °F	T_{2t}-460 °F	T_{2t}/T_{1t}
0	1800	2970	3170	6.72	1940	3300	3520	7.36	1950	3300	3530	7.39
4	1440	2580	2170	5.88	1790	3180	3370	7.09	1870	3250	3460	7.26
8	1010	1920	1990	4.54	1570	2940	3090	6.57	1800	3170	3370	7.09
12	650	1200	1230	3.13	1300	2570	2680	5.81	1770	3160	3350	7.06
16	420	670	680	2.11	950	1960	2020	4.59	1600	2970	3130	6.65
20	300	370	380	1.56	630	1260	1290	3.24	1440	2770	2910	6.24
24	190	80	80	1.00	435	790	800	2.33	1210	2420	2510	5.50
28	---	--	--	----	305	430	440	1.67	882	1810	1860	4.30
32	---	--	--	----	180	80	80	1.00	594	1180	1210	3.09
36	---	--	--	----	---	--	--	----	370	610	620	2.00
44	---	--	--	----	---	--	--	----	180	80	80	1.00

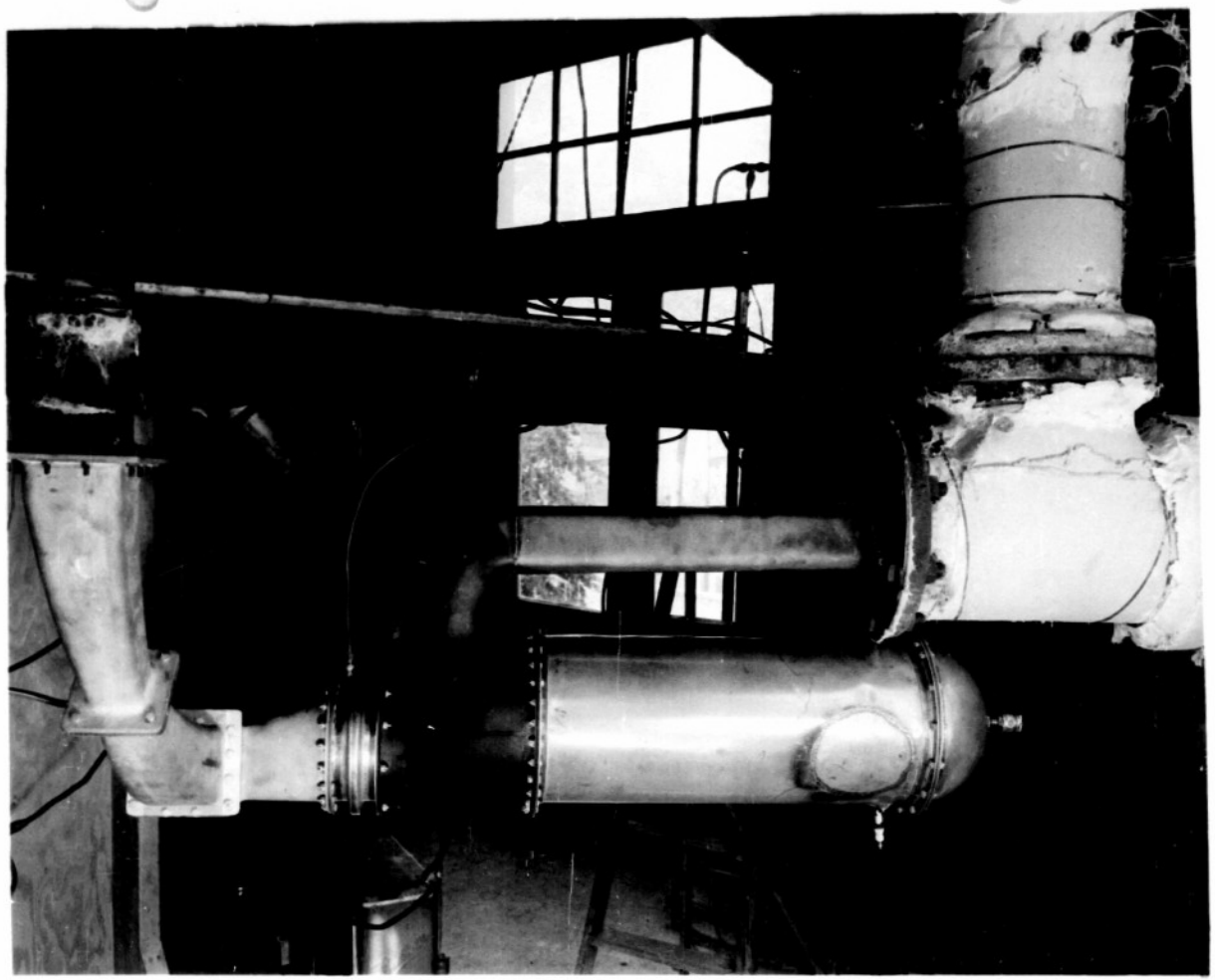

Figure 1.

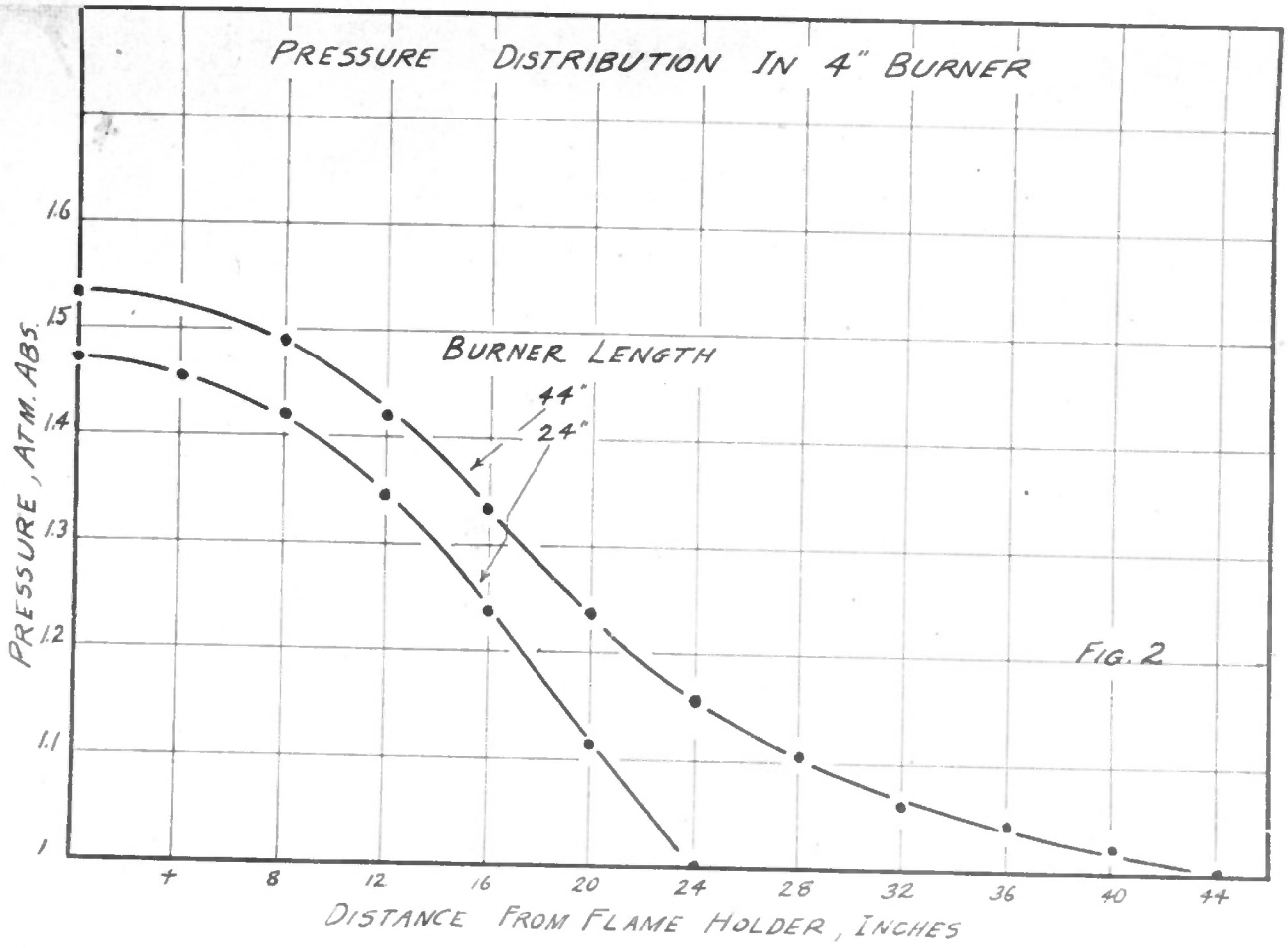
PRESSURE DISTRIBUTION IN 4" BURNER
BURNER LENGTH
44"
24"
PRESSURE, ATM. ABS.
1.6
1.5
1.4
1.3
1.2
1.1
1
4
8
12
16
20
24
28
32
36
40
44
DISTANCE FROM FLAME HOLDER, INCHES

FIG. 2

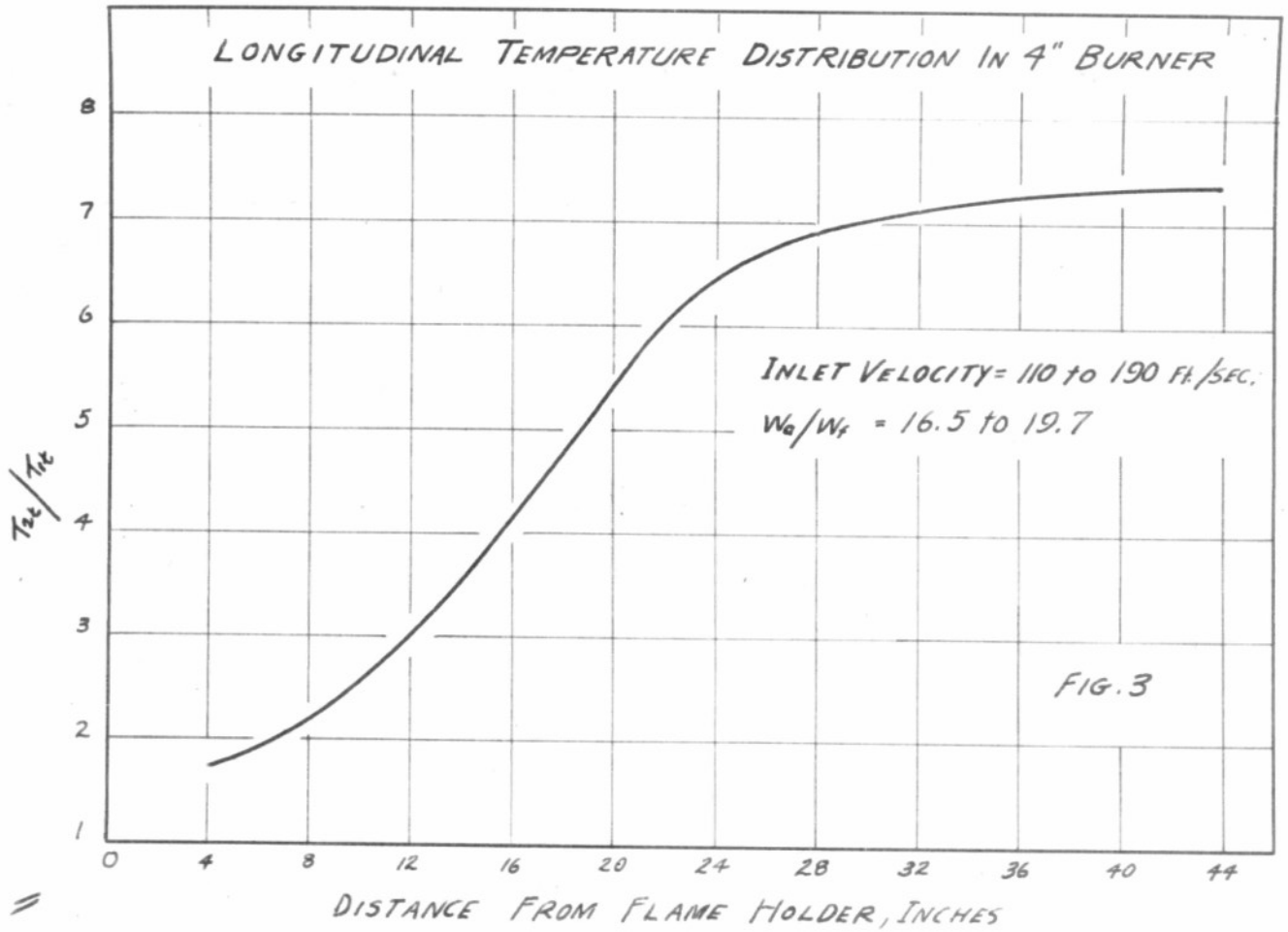
LONGITUDINAL TEMPERATURE DISTRIBUTION IN 4" BURNER
INLET VELOCITY = 110 to 190 Ft./SEC.
W_a/W_f = 16.5 to 19.7
T_{ae}/T_{ic}
1
2
3
4
5
6
7
8
0
4
8
12
16
20
24
28
32
36
40
44
DISTANCE FROM FLAME HOLDER, INCHES

FIG. 3

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U. S. National Bureau of Standards AUTHOR(S)	~~CONFIDENTIAL~~ C-5-12-7 DIVISION: Power Plants, Jet and Turbine (5) SECTION: Combustion Chambers (12) CROSS REFERENCES: Combustion - Mixture effects (23630); Combustion chambers - Testing (23865); Combustion theory (23950)	ATI- 8131 ORIG. AGENCY NUMBER NB-34 REVISION

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FOREIGN TITLE:

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COUNTRY	LANGUAGE	FOREIGN CLASS	U.S. CLASS.	DATE	PAGES	ILLUS.	FEATURES
U.S.	Eng.		~~Confid'l~~	Nov '45	10	4	photos, tables, graphs

ABSTRACT

Ignition and stable combustion in 7-in. diameter combustion chamber were possible up to maximum air velocity of about 160 ft/sec, but combustion efficiency was only 70%. Effect of chamber length in 4-in. diameter ramjet was investigated. Experiments indicated that with poor upstream flow distribution, it was very difficult to initiate smooth burning if the tail pipe extended more than 2 ft beyond flame holder. Short combustion chambers are easier to start under all inlet conditions.

T-2, HQ., AIR MATERIEL COMMAND — An TECHNICAL INDEX ~~CONFIDENTIAL~~ — WRIGHT FIELD, OHIO, USAAF

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Robert Storer
Chief, Records and Declassification Division

Attachments:
1. MDR request
2. OSD response letter
3. Document 4